Mold Remediation: How Complex Should It Be?

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ABSTRACT

Although mold growth in buildings has long been considered unsanitary, exposure control measures have been included in the cleanup process only recently. Current approaches to mold remediation vary substantially, ranging from investigators treating it as a hazardous material and to those who assign it a relatively low maintenance priority. While detailed guidelines for mold remediation are now available, their cost-effectiveness has never been evaluated. The need for formal planning, detailed oversight, specialized personnel, and stringent project controls should depend on the extent of contamination, potential exposure, and occupant sensitivity. Where the repair of moisture sources or mold growth is not feasible, remediation may be delayed or reduced in scope where alternative control measures are considered. During the remediation process, some migration of airborne mold can be expected even under full containment. With spatial containment, occupant exposure can be avoided by temporary relocation and detailed cleaning of the area.

INTRODUCTION

Until the late 1990s, mold control recommendations were typically very general:

- allergists suggested removal of mold-contaminated materials and cleaning the area (Kozak et al. 1980[1]);
- the Agriculture Research Service told homeowners to control dampness and treat with a bleach solution (USDA 1980[2]);
- microbiologists emphasized mold control in hospital wards with patients subject to opportunistic infection (Burge 1989[3]); and
- flood restoration experts included mold treatment as a step in the cleanup process (IICRC 1995[4]).

Although attention to indoor air quality increased in the 1980's, control measures for mold remained general. A 1984 publication recommended repairing leaks, maintaining relative humidity below 70%, carefully discarding contaminated items, wearing respirators during cleanup, and HEPA vacuuming followed by disinfection (Morey et al. 1984[5]). At this time, mycotoxins were recognized as a potential component of fungi, but they were not considered to be a specific health threat to building occupants (ACGIH 1989[6]).

The first detailed mold remediations were performed by general contractors using critical barriers or containment (Light et al. 1989[7]; Light et al. 1991[8]). Initial approaches changed with the published assumption that toxogentic fungi presented a significant health threat, justifying the use of asbestos abatement methods (Morey 1992[9]).

Guidelines for mold remediation were first published in 1993, based on control of *Stachybotrys* as a

toxogenic mold (NYCDOH 1993[10]). These were subsequently reflected in the recommendations of other organizations (ISIAQ 1996[11]; AIHA 1996[12] Health Canada 1995[13]).

The New York City Department of Health (NYCDOH[14]) updated their mold Guidelines in April 2000 based on best professional judgment as to control levels needed to minimize health effects. The stringency of worker protection and area containment increases with area. Assessment, cleaning, and clearance are other issues addressed. Greater exposure protection is encouraged for sensitive individuals. Guidance issued by ACGIH and EPA deviate only slightly from NYCDOH. For example, ACGIH (1999[15]) allows N-95 disposable respirators when remediating large areas (NYC recommends HEPA-filtered, full-face) and requires containment for medium sized areas (NYC does not). EPA (2001[16]) also requires containment for medium sized areas. Requirements of these commonly cited mold guidelines do not appear to be based on specific data or documentation.

CDC[17] has also issued a guideline for building mold in health care facilities with extremely sensitive patients subject to fungal infections (stem cell recipients). These address special ventilation, barriers, and cleaning. Although medical surveillance is emphasized, routine environmental monitoring is not.(17)

REMEDIATION OBJECTIVES

At the present time, mold remediation practice is polarized across the U.S., with some practitioners treating building mold as a hazardous material (implementing extremely stringent procedures to eliminate "toxic mold") while others continue to assign it a low priority and take no specific precautions. Specifications for mold cleanup are ideally based on exposure control objectives, the extent of contamination, and site-specific logistics. Some common objectives of remediation projects are:

- Restore building conditions (repair water damage, control musty odor, etc.)
- Establish conditions acceptable for the general population (minimize minor allergic reactions, etc.)
- Protect extremely sensitive individuals (e.g., minimize the potential for fungal infection in immuno-compromised individuals).

In general, project controls are least stringent for building restoration only and greatest for protection of sensitive patients.

While the above project objectives are based on well-documented effects of building mold growth (ACGIH 1999), many projects have recently been based on perceived or assumed health effects of "toxic molds." Recent reviews have shown that mycotoxins is not associated with building occupant symptoms (Page and Trout 2001[19]) (Robbins et al. 2000[20]). In this regard, the presence of common environmental molds labeled "toxic" should not be the basis for determining the stringency of remedial procedures.

SCOPE OF MOISTURE AND MOLD REPAIRS

There is general agreement between the various mold remediation guidelines that moisture sources must be resolved while materials supporting mold growth are replaced or treated and adjacent dust should be removed.

When the dominant concern is the presence of "toxic" molds, assessment may be based primarily on sampling, often with less attention paid to moisture dynamics and the extent of visible mold growth. Underlying moisture issues and the extent of visible mold growth may be better understood when the types of mold present are not considered important.

Identifying the underlying cause and driving force responsible for a building moisture problem is necessary for effective mold repair. Common problems which should be identified or ruled out may include:

- envelope leakage (roof integrity, inadequate flashing, caulking maintenance, doors or window installation, joint construction)
- exterior drainage
- wall constructed without drainage plane (EIFS)
- incorrectly placed vapor or air barrier (e.g., vinyl wallpaper)
- plumbing leaks
- standing water in HVAC system
- pipe sweating
- inadequate dehumidification (insufficient exhaust, building under negative pressure, low cooling load)
- exposed materials during construction

Where moisture dynamics are not obvious, further investigation based on building plans, facility history, and a systematic inspection may be needed, in some cases, involving the use of a specialized instrumentation (e.g., moisture meter).

Mold guidelines state that porous materials should generally be replaced and that other surfaces may be cleaned. Field experience has shown that alternative approaches can also be considered. For example, where it is infeasible to remove moldy wood, it might be sanded and encapsulated to remove as much surface growth as possible and minimize spore release.

In general, the feasibility of repairing moisture and mold growth may be considered as easy, moderately difficult, or difficult:

1. **Easy Repairs**

    - ceiling tiles
    - accessible hard surfaces

2. **Moderately Difficult Repairs**

    - accessible sheetrock or insulation
    - treatable wood

3. **Difficult Repairs**

    - inaccessible core walls
    - EIFS walls
    - widespread condensation behind vinyl wall covering

While guidelines imply that mold growth should be remediated immediately and completely, there are circumstances where this ideal cannot be achieved (e.g., structural or fire protection constraints). In cases where mold and moisture controls must be implemented over time, interim measures can be used to limit exposure and the risks may be considered insignificant (e.g., if hypersensitive individuals are not exposed). Such controls may include modifying air pathways (e.g., sealing penetrations or changing pressurization), intensifying housekeeping, dehumidifying, periodic mold treatment, or temporary encapsulation.

In limited circumstances, treatment of some mold contaminated surfaces may never be feasible (e.g., cannot be accessed or firewall cannot be compromised). In these cases, partial control measures might be followed by air sampling to assess ongoing air quality with residual mold left in place.

WORKER PROTECTION

Little information has been developed regarding the potential health risks faced by mold remediation workers. OSHA and NIOSH have not specifically addressed worker protection requirements based on statutory requirements. As a result, measures recommended by the various mold guidelines have little quantitative basis and no validation.

The 1993 NYCDOH Guidelines were quite restrictive as to who could perform mold remediation. General maintenance personnel were allowed for only very small projects (≤ 2 ft^2 [$0.2m^2$]), providing they were in a full OSHA Respiratory Protection Program. Projects ranging from 2 - 30 ft^2 (0.2 to $2.7m^2$) required workers who received formal mold training and were free of specified medical conditions. Larger projects required trained hazmat workers. In 2000, NYCDOH changed these specifications to allow maintenance personnel to perform remediation where mold coverage in individual work areas was small to moderate (e.g., up to about 30 ft^2 [$2.7m^2$]). Hazmat-type personnel under the supervision of a health and safety professional experienced in mold investigation were recommended for larger projects.

Where building mold is assumed to be a hazardous material (e.g., mycotoxic effects likely), remediation is more likely to be conducted by specialized contractors and consultants. In many cases, equally effective services may also be available from either in-house custodial or maintenance personnel or commercial cleaning and restoration contractors. Although not formally trained in microbiology or hazardous material management, such personnel have practical experience in sanitizing and repair procedures, which, in some cases, may be combined with site-specific knowledge of the affected building. Mold remediation projects conducted by a contractor with an asbestos abatement background under the direction of an environmental consultant basing decisions primarily on microbial sampling does not necessarily result in more effective remediation.

Respiratory protection requirements can also determine who is permitted to perform mold remediation. Where guidelines recommend a disposable (N-95) respirator, OSHA requirements for medical examinations, detailed documentation and formal training are waived where disposable respirator use is voluntary. Requirements to implement the administrative elements of a full Respiratory Protection Program may actually tend to discourage mold cleanup in some instances, especially where such work is incidental to other building maintenance and conducted on only a small-scale.

The updated NYCDOH Guidelines approved less stringent worker protection measures in many cases. Where fit-tested respirators with HEPA cartridges were originally required for any size job, the new Guidelines allow disposable respirators (N-95) in work areas with up to 100 ft^2 ($10m^2$) of mold. Disposable coveralls and full-face respirators with HEPA cartridges continue to be recommended for larger projects. While disposable coveralls play an obvious role in preventing the spread of contaminants beyond the workplace, specified skin protection (disposable gloves) is based on a concern for potential toxogenic effects, which had not been validated. Research is needed to determine if mold remediation work justifies personal protection more stringent than used for demolition involving other nuisance dusts.

BUILDING PROTECTION

Work associated with mold remediation potentially makes spores and other fungal fragments airborne (subject to subsequent settling and re-suspension). Objectives for site sanitation can be accomplished by

either preventing migration of contaminated dust from the work site or effectively protecting and/or cleaning adjacent surfaces. Site controls recommended by the various mold guidelines become more stringent with the extent of mold growth. The 1993 NYCDOH Guidelines did not specify how affected surface area was to be calculated, implying to many users that a cumulative building-wide total made up of isolated, minor mold problems would have to be remediated under the most stringent controls. The 2000 NYCDOH Guidelines recognize that airborne mold from isolated building areas is unlikely to be cumulative, stating that remediation controls should be based on contiguous square footage of mold growth (e.g., disturbance of mold within each building space can be treated independently). The 2000 NYCDOH Guidelines list several minimum remediation steps which should generally be implemented regardless of project size:

- remove visible mold;
- use dust suppression (e.g., moisten surfaces prior to cutting);
- remove material in sealed bags;
- clean work area and surrounding surfaces; and
- leave area dry and clean.

The 2000 NYCDOH Guidelines increased the threshold for triggering full containment maintained under negative pressure (including airlock and decontamination chamber with work conducted by hazmat personnel), from a cumulative mold area of 30 square feet throughout the building to 100 contiguous ft^2 ($10m^2$). They also delete the 1993 requirement for air monitoring during and after all large mold remediations, leaving inspection as the primary tool of project oversight and quality control.

The NYCDOH Guidelines state "The listed remediation methods are not meant to exclude other similarly effective methods." In this regard, alternative control measures which may reduce the need for full containment include:

- plasticizing only critical barriers (e.g., openings to adjacent areas);
- protecting the HVAC system (sealing supplies and returns or shutting off system);
- placing a drop cloth by the work site;
- maintaining only a slight negative or neutral pressure;
- recirculating air through a portable HEPA filter;
- cleaning of all surfaces potentially impacted by the remediation work (including areas beyond the immediate work site); and
- using the least dust-producing tool or procedure.

An important goal of mold remediation is to prevent migration into adjacent building areas, particularly if they are occupied. The tolerance implied for dust migration allowed in the NYCDOH Guideline is somewhere between housekeeping for general dust and decontamination procedures for lead or asbestos abatement.

Little data is available on the extent and duration of mold migration from remediation sites and the effectiveness of containment measures. Four published case studies present air monitoring data adjacent to contained or partially contained mold remediation sites, each showing some leakage beyond the work area (Weber and Martinez 1993[22]; Rautiala et al. 1998[23]; Light et al. 1989 and 1991). Monitoring data from the first case suggests that background air quality concentrations were maintained adjacent to only three of seven containments monitored, with airborne spores substantially elevated by the other four. Monitoring after remediation was completed showed air quality had returned to low concentrations in all areas (Weber and Martinez 1993).

The second case presented monitoring results adjacent to three containments. Some mold leakage was

detected in the containment under neutral pressure and in the containment with local exhaust. Air quality was maintained by the containment under negative pressure (Rautiala et al. 1998).

The third case compared air quality inside mold remediation containments with adjacent buffer zones (vacated for duration of the work) and nearby occupied areas. Mold concentrations were elevated in the buffer zones due to a failure by the contractor to consistently implement required work practices. Airborne mold concentrations in occupied areas remained very low, however. Follow-up testing in the buffer zones showed concentrations returned to background levels (Light et al. 1991).

The final case examined remediation inside critical barriers (incomplete containment, neutral pressure). Seven of eight air tests in an adjacent occupied area were within normal background, (airborne fungi elevated). Air sampling results at the end of remediation and one year later at this site had returned to the background range (Light et al. 1989).

These findings suggest that under field conditions airborne mold may migrate from the remediation area due to various design, construction, or maintenance deficiencies related to attempted containment. Elevated concentrations in adjacent areas were shown to be temporary and were later resolved. In the case studies, occupant exposure was apparently avoided by either conducting the work after-hours or vacating a buffer zone around the work area.

Containment failures allowing such mold migration may be caused by deficiencies in design or work practices. These findings suggest that, under field conditions, containments do not completely prevent mold migration from the work site. In some cases, remediation without full containment can provide comparable control.

The NYCDOH Guidelines imply that remediation oversight can generally be based on verification of work practices and indicators of potential contamination such as visible dust and smoke tube observations.

OCCUPANT PROTECTION

The most effective protection of building occupants during mold remediation is based on a combination of control measures, including temporary evacuation, site sanitation, and containment. Considerations are often different for the general (non-sensitive) population versus sensitive individuals.

Controls specified by the NYCDOH Guidelines assume average conditions (e.g., building remains occupied with only general population present), with flexibility allowed where conditions differ significantly. For example, where immuno-compromised occupants could be exposed, or exceptionally dusty demolition processes are involved, the threshold for using full containment might be reduced. Conversely, less stringent measures may be considered where potential exposures will be negligible (see Example 3).

Example 3. Variance From Full Containment (extensive mold growth; no sensitive occupants present):

- conduct work when building is vacant or a large buffer zone can be cleared of occupants
- maintain critical barriers
- implement enhanced dust control measures for removal operation
- perform enhance cleaning of adjacent areas

In addition to specifying measures for controlling airborne mold, the NYCDOH Guidelines include these provisions for further protection of building occupants:

- vacate immediate area during remediation;
- move any mold-sensitive individuals from adjacent building areas during remediation activity.

Consideration for vacating the entire building is reserved for cases of widespread contamination with medically associated illness throughout the building. A provision in the 1993 NYCDOH Guideline required immediate evacuation where an air sample exceeded 1000 cfu/m^3 of *Stachybotrys chartarum.*

With a primary objective being to protect occupants from exposure to building mold at levels which could cause adverse health effects, two populations must be considered, general and sensitive. Many occupants appear to tolerate low background concentrations of mold (the "general population"). Where large-scale mold remediation is conducted, conditions should generally be acceptable for the general population when either:

1. work is conducted within a full containment; or
2. work is conducted off-hours followed by detailed cleaning of surrounding areas; or
3. a buffer zone is vacated around the work area, which is subsequently cleaned before occupancy.

Where potentially sensitive individuals are involved, they are best protected by relocation. Ideally, each patient's condition should be verified medically (e.g., a physician finds they have a history of mold sensitivity or susceptibility to opportunistic infection). With current publicity concerning potential mold effects, some occupants may incorrectly perceive they are sensitive to mold exposure. Issues of sensitivity are best resolved with specialized medical assessment (ACGIH 1999). When true sensitivity is confirmed, all efforts should be made to relocate the patient from any areas with potential exposure to remediation activity. In situations where this is not feasible (e.g., mold remediation in a health care facility with continuous occupancy of immuno-compromised patients), all feasible controls to minimize exposure should be considered (e.g., full containment of even small work areas).

VERIFICATION

A clearance step is included in many mold remediation projects to verify that specified control objectives have been accomplished and that the area is acceptable for reoccupancy. An important revision of the NYCDOH Guidelines was made in relation to how remediated areas are cleared. The 1993 version specified air monitoring after many projects with areas failing to be cleared if any detectable *Stachybotrys chartarum* was present. The 2000 Guidelines made visual inspection the primary verification tool (remediated area must be found clean and free of visible contamination). Clearance air monitoring is reserved for the largest projects (e.g., exceeding 100 contiguous ft^2 [$10m^2$]) with interpretation of data left to professional judgement.

A comparison of visual with "quantitative" clearance should consider the following:

- there are no accepted health-based standards for airborne mold
- there is no precise formula for distinguishing normal background mold from contamination
- airborne mold may vary widely by time and location (including a "memory effect" where readings immediately after remediation do not reflect longer term levels).
- specific monitoring methods each have limitations (e.g., inaccuracy of spore trap identifications, delay for impactor sample analysis).

Failure to recognize the normal variability of airborne mold has led to false negative conclusions for some projects (e.g., mold growth has been completely removed, but the area fails clearance). Trace

findings of molds considered to be "toxic", or an unacceptable ratio comparing the results of outdoor air or to indoor mold may be the basis for such clearance failures. Conversely, false positive results can occur when an inadequate visual inspection fails to identify improper work practices, while test results are interpreted to represent normal background concentrations.

DISCUSSION

Comparison of some typical project settings illustrates the range of general response options available for remediation.

Case 1 (least stringent) involves minor mold growth in a home with no health issues involved. Objectives are to generally restore the condition of the home (including elimination of musty odor). In this case, moisture sources and surface growth are repaired where feasible and minor residue is partially tolerated in the cleanup.

Case 2 involves major mold growth in an office building with no known sensitive individuals. Objectives are to restore building conditions and to minimize the risk of minor allergies. Remediation is performed either after hours or with occupants temporarily relocated. Moisture sources are identified and repaired. Surface growth is repaired under partial containment and the general area sanitized.

Case 3 (most stringent) involves major mold growth in a health care facility with the objective being to minimize exposure of nearby immuno-compromised patients. All moisture sources and visible growth should be repaired with verification. Mold remediation is performed under full containment with all potentially affected surfaces sanitized.

CONCLUSIONS

1. While the principles of mold remediation are generally applicable (e.g., control moisture sources, repair surface growth, protect nearby surfaces), the complexity of the process can vary considerably. For example, where the extent of mold growth is minor and/or potential risks to occupants are minimal, an informal approach may be acceptable, using less detailed procedures, less stringent controls, and personnel who are not specialized.

2. Building mold growth can usually be assessed solely by visual inspection of potentially impacted surfaces. Similarly, control and verification of the remediation process can often be based on visual observations (testing optional). Considering the variability of normal airborne concentrations and lack of health-based standards, microbial testing is not recommended for most situations.

3. Repairs of moisture sources and mold growth range from simple to complex. In the latter cases, implementation may often be phased over a period of time, and full implementation may not be possible. Interim or partial controls may be sufficient to meet air quality objectives (air monitoring may help track progress).

4. Alternative approaches can be considered to protect against exposure to mold during remediation activity. These include full or partial containment, surface protection, cleaning, and temporary relocation of occupants.

5. Mold remediation guidelines have little basis in risk assessment, and the effectiveness of most procedures has never been verified. Cost-effective measures for protection of workers, building surfaces, and occupants have not been established.

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